

The Prototype Validation Exercise (PROVE) for EOS Land and Atmosphere Products

Jeffrey L. Privette¹ and Gregory P. Asner²

¹NASA's Goddard Space Flight Center, Code 923, Greenbelt, MD 20771. Tel. 301-286-5340; Fax. 301-286-0239; jeff.privette@gsfc.nasa.gov

²Stanford University. Tel. 605-725-0927; Fax. 605-725-2199; gpa@pangea.stanford.edu

Abstract -- Three Earth Observing System (EOS) instrument teams (MODLAND, MISR and ASTER) joined forces in May, 1997 to conduct an 11-day field validation campaign in a desert grassland near Las Cruces, New Mexico. The exercise was held at the USDA-Agricultural Research Service's (ARS) Jornada Experimental Range, an expansive and relatively flat plain hosting a mixture of short grasses and shrubs. Most macroscopic land variables affecting the radiation environment, and the radiation environment itself, were measured. Moreover, a large variety of aircraft data (e.g., AVIRIS and LIDAR) and satellite data (AVHRR, Landsat TM, SPOT, POLDER, GOES) were acquired. We describe the site, the experiment, and some initial results from PROVE. The latter will be published in a forthcoming special issue of Remote Sensing of Environment. The data from PROVE are available to the public and may be ideal for some scaling and remote sensing studies.

INTRODUCTION

The EOS Terra sensors will provide unprecedented accuracy in sensor calibration, georegistration and atmospheric correction. Since 1990, instrument teams have been developing algorithms for EOS standard land products. For example, the MODIS Land Discipline Team (MODLAND) will generate gridded global products of albedo, surface temperature, leaf area index, fire-burned area and other parameters. These products will, in most cases, be available in near-real time at no cost to the user community.

However, advanced sensors and algorithms do not guarantee advanced product accuracy. A well-supported and sustained validation program is required to provide timely feedback to algorithm developers, such that through iterative improvements, superior products will result. Although global validation was largely neglected with previous land remote sensing missions, it is required of the Terra instrument teams and validation investigators.

Because conducting a field measurement program requires both experience and testing, several Terra instrument teams (MODLAND, MISR and ASTER) organized the Prototype Validation Exercise (PROVE). This campaign, conducted in a desert grassland near Las Cruces, NM in May, 1997, was designed as an EOS pathfinding activity for the coordination, collection and active archiving of relevant field data and the subsequent validation of remote sensing land products at scales commensurate with those of the Terra sensors.

The goals of the Grassland Prototype Validation Exercise (PROVE) were to 1) gain experience in the collection of field data for EOS product validation, 2) establish standard data measurement, scaling and archiving protocols for use within the EOS Validation Program, and 3) augment a field data archive used to test remote sensing algorithms.

APPROACH

EOS validation scientists have identified a large number of global test sites for Terra validation [1, 2]. At many sites, above-canopy towers will be used to continuously measure aggregate landscape variables (e.g., albedo). These will be complimented with within-canopy measurements (e.g., structure and absorbed radiation), and correlative relationships will be developed. By extrapolating the frequent but spatially limited tower and ground-based data sets with episodic aircraft remote sensing data, product validation can potentially be conducted year-round over fairly large and statistically significant areas in a relatively inexpensive and efficient manner. Although this plan seems conceptually sound, the importance of validation to EOS required that key parts be prototyped well before Terra's launch. This need led to the PROVE campaign.

LOCATION

The Jornada Experimental Range is primarily a flat, desert grassland, and is located 37 km north of Las Cruces, NM. It represents the northern extent of the 0.5 million ha Chihuahuan Desert, the largest of North America's deserts. Although Jornada was largely covered with grasses prior to livestock grazing, encroaching shrubland has been replacing the grassland in a north to south progression since the early 1900s. Currently, there are about 8000 ha of grassland, 12000 ha of transitional grass and shrub land and 35000 ha of shrubland (primarily mesquite, *Prosopis glandulosa*). The soil consists of well-drained sand. The shrubland contains sand dunes topped by mesquite shrubs with virtually bare interdunal spaces (Fig. 1).

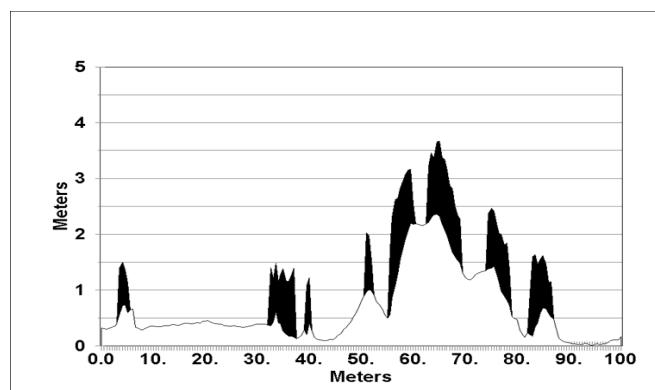


Fig. 1. A transect of vertical displacement information derived from aircraft LIDAR data. The black forms represent shrubs, and the white forms represent sand dunes. Courtesy of J. Ritchey [3].

The Jornada Experimental Range is ideally suited for EOS validation activities. First, it features a well-equipped laboratory and machine shop, a 30 m tower (at the transitional site) and an on-site truck with a cherry picker capable of reaching heights up to 30 m. Moreover, the infrastructure is highly concentrated, such that most of the range contains little or no development. Second, there is minimal topography, which can complicate remote sensing and field efforts. Third, the high desert has a comparatively clear atmosphere and little precipitation. Finally, the site has had a rich history of remote sensing and ecological research.

MEASUREMENTS AND DATA

More than 40 researchers, representing 12 institutions, participated in PROVE. The 11-day campaign was punctuated by a highly uncharacteristic rainfall event on day 3 (22 May). Skies were generally partly cloudy, atypical for this location and time of year, with a fairly persistent thin cirrus cloud layer and occasional cumulous clouds. Nevertheless, periods of clear skies on several days allowed investigators to achieve nearly all data collection goals.

Three types of data are required if errors in remote sensing products are to be attributable to their sources. These include 1) macroscopic parameters of the soil, canopy and atmosphere which affect the radiation environment, 2) metrics required to scale point measurements to the satellite product resolution, and 3) the radiation environment itself (e.g., surface irradiance, angular upwelling radiances). Any variables not meeting these criteria were considered extraneous to PROVE.

Data were collected at various scales, including leaf, scene component (e.g., individual shrubs), homogeneous site (e.g., grassland site), and heterogeneous landscape (i.e., Jornada-wide) over the period. The key parameters measured included,

- Canopy-absorbed radiation (PAR)
- Scene component spectra, albedo and angular radiance
- Scene LIDAR, bidirectional and hyperspectral reflectance
- Surface temperature
- Atmospheric spectral/angular radiance
- Shrub and canopy structure
- Leaf/stem/plant area index
- Leaf/stem angular and spatial distributions
- Leaf spectra and structure
- Meteorological and atmospheric information.

The transitional and grassland sites were measured most intensively. Three spatial sampling strategies were used, including measurements at equal distances along long transects, measurements of scene components, and randomly-spaced measurements over the landscape.

Aircraft and Satellite-based measurements

Three research aircraft overflew Jornada during PROVE. MODLAND flew a Cessna 185 aircraft along the solar principal and perpendicular planes at several times of day and at all three sites. The plane carried an Exotech 4 band

radiometer, mounted to allow off-nadir pointing, as well as a nadir-pointing thermal radiometer. The USDA flew a one-bounce laser profile altimeter (LIDAR) and videotape imager. Finally, the NASA ER-2, carrying the AVIRIS spectrometer and a still-frame camera, overflew the Jornada and neighboring Sevilleta Long Term Ecological Research (LTER) sites. The Thermal Infrared Spectral Scanner (TIMS) and Thematic Mapper Simulator (TMS) were flown over Jornada on 19 June. Table 1 summarizes the remote sensing data collected during PROVE.

Table 1. Downward-looking remote sensing data collected during PROVE. Upward-looking sensors were also used.

Sensor	Height (m)	Spatial Res. (m)	View Angle Range (°)	Max. Wave- length (mm)	No. Bands
Exotech	2	0.5	0	0.8	4
SE590	3	0.8	±60	0.9	46
ASD FR	1	var.	0	2.5	215
CIMEL	30	0.6	±70	1.0	2
PARABOLA	30	2.6	±70	11.0	8
Air. Exotech	100	30	±45	0.8	4
LIDAR	200	0.1	0	0.9	1
AVIRIS	2e4	20	±15	2.5	224
Landsat TM	>7e5	30	±7.5	12.5	7
AVHRR	>8e5	1100	±55	12.0	5
SPOT HRV	>8e5	20	±27	0.8	3
POLDER	>8e5	7000	±51	0.9	4
GOES	>3e7	1000	fixed	12.0	5

Coarser scale remote sensing data were acquired via satellite. The University of Colorado-Boulder collected 137 scenes of day and night NOAA-12 and -14 AVHRR HRPT (1.1 km) data through the campaign. MODLAND purchased 480 scenes of GOES-8 data, at 30 minute intervals, which were available on-line in near real-time. The ASTER team conducted a vicarious calibration exercise over White Sands National Monument, approximately 30 km to the east of Jornada, in conjunction with Landsat 5 and SPOT-2 passes. The European Space Agency provided five POLDER scenes for the period.

INITIAL ANALYSIS AND RESULTS

More than 10 PROVE studies have been submitted to Remote Sensing of Environment, expected to be published in early 2000. We outline several example results below.

White *et al.* [4] investigated several traditional and new methods to assess shrubland LAI and fractional cover. They found that a data from a Dycam Agricultural Digital Camera (ADC) was among the most consistent and accurate (Fig. 2).

Qin and Gerstl [5] developed a new L-system model of yucca and mesquite shrubs, with an anisotropic soil background, combined into one scene. Radiosity calculations from the scene showed extremely good agreement with atmospherically-corrected POLDER, AVHRR and tower bidirectional reflectance data (Fig. 3). Walter-shea *et al.*

(unpublished) measured individual shrub bidirectional reflectances (Fig. 4).

CONCLUSIONS

Grassland PROVE provides a successful prototype of an episodic, tower-based campaign that can be duplicated. Keys to this success included 1) focusing only on variables which related to actual EOS products or the scene radiation environment, and 2) conducting the campaign at an existing site with significant infrastructure.

Two significant obstacles were encountered. First, the structure of desert shrubs made some canopy measurements exceedingly time consuming. However, systematic non-destructive measurements of shrubs targeted for destructive sampling allowed useful correlative relationships to be determined. In general, it would be useful to develop rigorous correlative relationships for each phenological stage, such they may be used throughout the EOS era. Second, deployment of the ER-2 from California required an eight hour lead forecast of cloudiness. This is of course difficult and errors can be costly. In contrast, the Cessna was deployed from the Las Cruces Airport, approximately 40 km away. This plane was able to adjust its schedule to take advantage of more briefly enduring clear skies.

An excellent data set now exists for a complex yet spatially extensive land cover. These data are available for scaling and remote sensing studies and radiation model validation, and will ultimately reside at the Oak Ridge Data Active Archive Center (DAAC). Further campaign details are available at: <http://modarch.gsfc.nasa.gov/MODIS/LAND/VAL/prove/grass/prove.html>.

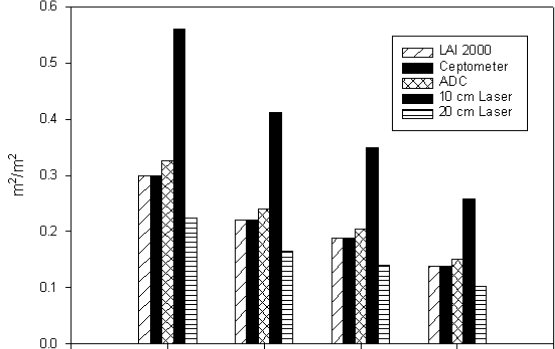


Fig. 2. Five different leaf area index estimates from four different sites. Laser implies airborne LIDAR, and ADC denotes Agricultural Digital Camera. Courtesy M. White.

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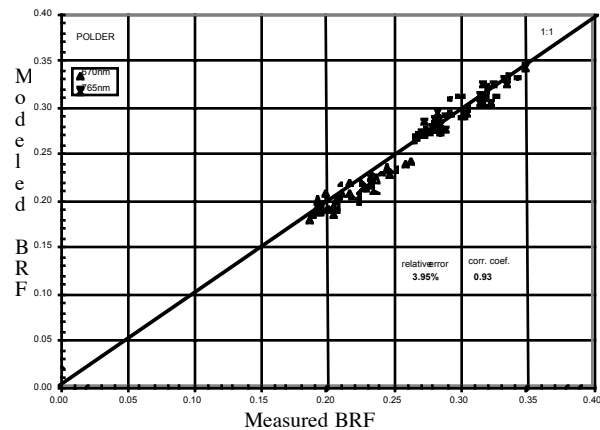


Fig. 3. A comparison of forward-modeled reflectance from an L-systems/radiosity model and atmospherically-corrected POLDER data. Courtesy W. Qin.

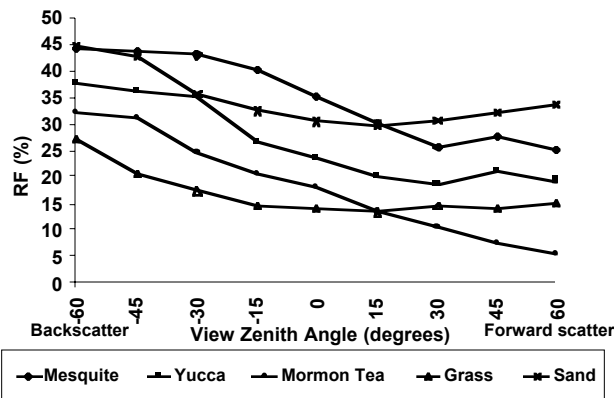


Fig. 4. Shrub-level bidirectional reflectances in the near infrared. Courtesy B. Walter-Shea.